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new

5 YEAR PLAN 1977-1982

ISSUE PAPER 1:
MUNI METRO:
ISSUES AND STRATEGIES

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INTRODUCTION

This series of issue papers, of which this document is the first, are intended to stimulate discussion on various issues confronting the Railway, whose resolution will shape the directions taken by the Five Year Plan itself. Development of such a Five Year Plan is now mandated by both federal and regional (Metropolitan Transportation Commission) requirements.

In about two years, MUNI's new streetcars, known as "Light Rail Vehicles" or LRVs, will begin operating in MUNI's Market Street Subway. This subway-surface operation will be known as MUNI METRO.

This paper discusses alternatives related to three sets of inter-related issues confronting MUNI METRO operation which need to be resolved before full service of all five streetcar lines into the Market Street subway can be achieved. The issues concern operations and scheduling, staging sequences, and opportunities for reconstruction and expansion to improve the system and increase operating efficiency. A recommended course of action is then suggested.

The principal operational question centers around the issue of coupling: is en-route, in-service coupling of cars into trains necessary, is it desirable, when, where, and how will coupling be performed? Staging issues focus on the obvious question of how to sequence the transition from a five-line surface streetcar operation to a five-line MUNI METRO subway/surface operation. Opportunities for reconstruction and expansion at this time involve modification of terminal facilities at Embarcadero as well as opportunities for additional MUNI METRO revenue services.

The timely comments of Don Cameron, Merrill R. Cohn, H.D. Quinby and Gerald P. Cauthen on the preliminary draft of this paper are gratefully acknowledged, although the opinions expressed here remain my own and those of the MUNI Planning Division staff. This paper does not necessarily represent the opinions of Railway management, nor does it necessarily express adopted PUC or City policy.

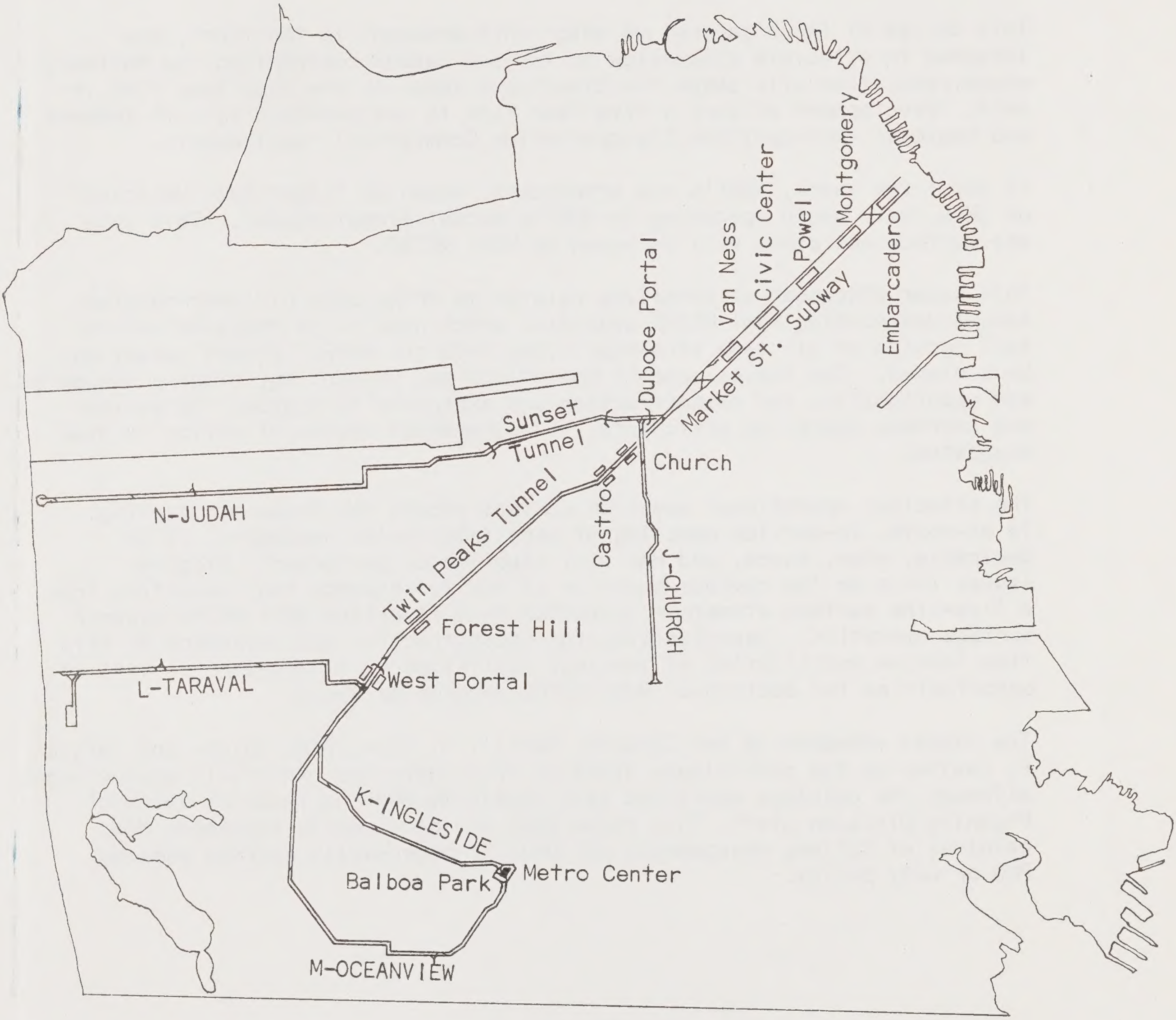


Figure 1.
MUNI METRO SYSTEM
Existing and committed facilities (Not to scale)

1. OPERATIONS AND SCHEDULING

A. Background

The present designs of the MUNI METRO system components, including cars, stations, signal and power supply systems, etc., are all predicated on a proposed operating strategy using single LRVs on the surface and train operation in our subway. As proposed, K-INGLESIDE, L-TARAVAL and M-OCEANVIEW cars would operate as surface streetcars on the lines' outer branches, coming together at West Portal Station. At this point, K, L and M cars, with passengers on board, are to be coupled into three- and four-car units, and continue inbound as trains.

Similarly, J-CHURCH and N-JUDAH cars would be formed into two- or three-car trains at the inbound subway portal on Duboce Avenue east of Church Street. Peak headways on each individual line would be about four minutes. J-N and K-L-M trains would be merged alternately into the Market Street subway at the Duboce and Market subway junction and operate on a two-minute combined peak headway to the Embarcadero Station terminal. Outbound, the process would be reversed, with trains separating into individual cars at Duboce and West Portals.

The rationale for this operating strategy is to allow high capacity to be achieved (by use of multi-car trains) despite relatively long, two-minute subway headways, as compared to the 50-second average headway of present Market Street surface streetcar operations. The present physical design of Embarcadero terminal facilities effectively prevents turning trains at the Embarcadero Station at significantly less than a two-minute headway, thereby limiting the number of trains which can be operated each hour to about 30. Thus, subway capacity will be constrained by terminal capacity, not by line capacity. (See pages 12-15 and Appendix B.)

B. Scheduling and Reliability

Implicit in a smoothly functioning coupling operation as has been proposed, with alternate J-N and K-L-M trains merging into the Market Street trunk subway, is the requirement that trains can be dispatched from the coupling points at regular intervals. If trains are not dispatched regularly, delays will be incurred--either at the Duboce-Market junction or at Embarcadero--and capacity is ultimately sacrificed.

For trains to be dispatched from the coupling points at regularly scheduled intervals, it is essential that individual cars arrive at the coupling points at regularly scheduled times. In any event, some delay to passengers in any "first" car is inevitable, as other cars arrive and couple behind it. If these other cars do not arrive as scheduled, additional delay is incurred as the first car or cars of the train have to await the late arrival of the last car or cars. If "short trains" are dispatched before all scheduled cars arrive, then outbound schedules will be haphazard as these will depend on full trains being able to depart Embarcadero as scheduled. Alternately, inbound trains could leave coupling points as soon as three to four cars have arrived to make up a train on a random basis. But then waits are always going to be part of

the operation and the average standing delay at coupling points will be on the order of two minutes (half the peak headway for trains leaving each portal).

Extensive studies of the value of time to transportation users have shown that time spent waiting is up to twice as "expensive" as time spent travelling: most people would rather spend four minutes travelling than two minutes waiting. Hence, in terms of attracting and serving passengers, many of the advantages of building the subway in the first place would be lost if there regularly are more than minimal delays at the portals.

In summary, delays will occur unless timely arrival of cars from the outer ends of lines can be assured. But on the outer branches LRVs will continue to operate as surface streetcars in mixed traffic--so precise arrivals will be no more certain than at present. In consequence, coupling operations will represent complex scheduling problems, with inevitable built-in delays for passengers of perhaps two (and up to four) minutes, including the times required for actual coupling.

Coupling then will entail difficulties with respect to scheduling, including built-in delays to passengers (which will have to be reflected in schedules), questions of when to dispatch and when to hold trains, and problems of how to recover from schedule irregularities.

C. Safety

It has been alleged that coupling of LRVs will result in increased accident exposure for the MUNI METRO LRV system. Principally, concern has been expressed over:

(a) hazards inherent in coupling
(b) hazard of coupling on a grade at Duboce Portal
(c) risk of "fall-on-board" type accidents.

It is likely that the case has been overstated, at least for cases (a) and (b). While exposure to such hazards would increase, and cannot be discounted quite as easily as correspondance from LT Klauder Associates suggests (See Appendix B), the risks from these potential hazards are probably acceptably small.

While there is a risk of accident whenever vehicles are brought close together and it is true that <u>not</u> coupling could eliminate the <u>need</u> for such situations to arise, the actual danger involved is no more than the hazards involved in any situation involving transit operation at close headways or transit mixed with automobiles in traffic. This risk would be an acceptable one, much as Klauder suggests.

Similarly, coupling on a downgrade will probably be no more problematic than coupling on the level, again as Klauder suggests, because gravity plus braking is likely to provide excellent control. However, because the potential of a "runaway" caused by brake failure does nonetheless exist, the situation should be avoided if possible. This risk, however, may also be an acceptable one per se.

The most likely source of accidents will come from falls-on-board. Inevitably, sometimes cars will couple somewhat hard, and falls-on-board will occur. Also, situations will arise where even a soft coupling will be hard enough to bring the case to court--even if the coupling procedure is followed to the letter. Will we be able to present a legal argument that a coupling was not "unreasonably hard"?

Answers are obviously unknown at this time. It seems reasonable however to conclude that while the risks of accident exposure from coupling may be acceptable if there are sufficient benefits, these benefits need to be carefully evaluated and en-route coupling should be avoided if such benefits are slight or illusory.

D. Line Capacity

A computer simulation program (RAPTRAN) was adapted and run to provide data on operating performance of LRVs in the Market Street Subway. Although the program does require a number of simplifying assumptions (such as linear acceleration and deceleration rates), the program provides reasonable estimates of LRV schedule performance. The logic of the program follows scheduled LRV units (or trains) over a simulated model of the subway, using data on block lengths, signal logic, allowable train speeds, estimated dwell times, vehicle acceleration and deceleration characteristics, etc.

The portion of MUNI's subway examined was limited to the critical segment between Van Ness and Embarcadero. The program was used to determine the effects on running times and schedule adherence caused by reductions in the headways of subway operations below two minutes. It was found that if congestion at the Embarcadero Station is not considered, trains could operate between Van Ness and Embarcadero at headways of as short as 90-seconds with the same running times, at the same speeds, and with the same full signal protection as with 2-minute headways. With 15-second dwells at stations, the running times between Van Ness and Embarcadero remain about 4.3 minutes for all headways down to 90 seconds with no interference between trains. Furthermore, if congestion at Embarcadero can be resolved, even at 60-second headways and despite some delays caused by the Automatic Train Protection system's responding to the relative closeness of trains, running times are still on the order of 4.4 minutes.

While 60-seconds does not appear desirable as a scheduled headway, this nonetheless indicates that there is sufficient slack with a 75-second headway that a schedule based on a 75-second headway could realistically be maintained.

Summarizing, the RAPTRAN simulation of MUNI's Market Street Subway operations suggests that if the bottleneck at Embarcadero can be removed, it is entirely realistic to schedule LRVs in subway operation on combined headways as short as 75 seconds with the existing train and signal systems, and without deterioration of subway performance.

(The possibilities of reconstructing the Embarcadero turnaround facilities are discussed separately below).

E. Options

If en-route, in-service coupling were not to be practiced at all, and assuming Embarcadero reconstruction makes 75-second subway headways feasible, a schedule could then be built to provide an average headway on each of our five MUNI METRO lines of 5 x 75 = 375 seconds, or just under 6½ minutes.

Such a schedule would contrast with present headways, and with those associated with the proposed en-route coupling, as follows:

	Present AM Peak	Present Mid-day	Present PM Peak	Proposed 75-second subway headway (no coupling)	Proposed 2-minute subway headway (with coupling)
J	5	7	5½	6½	4
K	4½	7½	5	6½	4
L	3½	7½	4½	6½	4
M	7½	7½	6½	6½	4
N	3	5½	3½	6½	4

Remembering that the comfortable capacity of a single LRV is somewhat over 1½ times that of the PCC, and also that subway operation downtown will enhance schedule reliability appreciably, it is apparent that single-unit LRV operation at a 6½-minute headway on each line will not be adequate.

However, Boston, Cleveland and Toronto, as well as literally dozens of European LRV operations, have been successfully running coupled trains of two or more PCC or LRV-type cars for years not only in subways and over private rights of way, but in mixed traffic surface operation as well. Without en-route coupling at portals--i.e., coupling only at yards and terminals--it is apparent that with limited 2-car LRV train operation (principally on lines L and N), 6½-minute headways could accomodate all of MUNI's present streetcar passengers, and still allow for a 50% increase in utilization.

We are then confronted with perhaps three options for MUNI METRO operation - again assuming resolution of the Embarcadero turnaround problem:

(1) Coupling of LRVs at portals - the original plan - with 2-minute subway headways and 4-minute peak headways on the five branches (J,K,L,M,N), and with likely delays averaging two-minutes inbound at Portals.

(2) No en-route, in-service coupling, with $6\frac{1}{2}$-minute average headways on all five branches, 2-car surface operation as required, and "Load and Go" operation, with no built-in delays at Portals.

(3) Selective coupling, combining elements of both strategies. Basic schedules would be built as under Option (2), but selective en-route coupling might be utilized to increase capacity or decrease delays if and when operationally convenient. For example, if two cars were to arrive simultaneously at West Portal, they might then be coupled under the supervision of the Inspector and continue inbound as a train; but otherwise, cars might operate as single units and not be held at the Portals.

Despite various assertions to the contrary, we do not have to couple en-route. It is true that the alternatives may delay full subway operations, but the choice is ultimately ours, and it is MUNI which will have to accept the consequences of the final decisions.

2. STAGING

A. Background

Despite the seemingly endless series of permutations of events which could give rise to a correspondingly large number of sequences for phasing into full MUNI METRO service (for example, 13 alternative operating schemes at various stages of construction were enumerated in a summary of "Operational Alternatives" drafted in October 1974), there are perhaps only two sequences which seriously merit consideration at this juncture, given decisions and events to date.

The Railway is extremely fortunate in that a new storage facility is being provided for the new LRV fleet at the Metro Center. This has the important benefit of providing us sufficient storage for both LRV and PCC vehicles during the transition period, eliminating storage per se as a constraint. (By comparison, storage was a critical element in the transition from our old to our new Flyer trolley coach fleet.) It also appears that maintenance of a mixed fleet during the transition can also be adequately accommodated at the Metro Center facility.

The principal decision concerning staging which has already been made is the choice of the N-JUDAH as the MUNI METRO "start-up" line.

This decision was predicated on a number of considerations, including:

---Given yet earlier decisions, the only lines which could have been made available from a standpoint of electrical support facilities at about the time a start-up would be feasible are the J-CHURCH, N-JUDAH or perhaps K-INGLESIDE.

---MUNI's subway start-up line should be either the J-CHURCH or the N-JUDAH, so that

(1) Church and Castro Stations are not needed immediately, thereby postponing that additional incremental cost, and

(2) by starting with a Duboce Portal line rather than a Twin Peaks line, the first line will be less overloaded-a line serving West Portal (and Castro) stations would tend to be overwhelmed by transferring passengers, while fewer people can be expected to transfer at Church and Duboce for the shorter trip to or from downtown.

---There are more opportunities for motor coach route changes dependent on N-JUDAH MUNI METRO service than on any of the other four lines, so that an N-JUDAH start-up will allow the earliest realization of service and cost benefits through restructuring of motor coach services.

---Because of the intensity of use by four streetcar routes, Church Street between Market and Seventeenth Streets will not be rerailed until at least most of our streetcar services are in subway operation. Consequently, if LRV operation commenced with the J-CHURCH, the J-line would have to be shut down again subsequently for replacement of track between Market and Seventeenth Streets, while N-JUDAH service will be less likely to require any subsequent extended interuption. (Because of both their smaller wheels and the added problems of rerailing an articulated car, the alternative to a bus substitution, namely LRV operation over portable cross-overs, is to be avoided if at all possible).

---The N-JUDAH is the heaviest single line of the five streetcar services, so the most heavily loaded line can be served first with the higher capacity LRVs. We will be putting the MUNI METRO service where it is needed most.

B. Two Options

Given this decision to inaugurate service on the N-JUDAH, two options exist for sequencing inauguration of service on MUNI's other four light rail lines:

(1) N-J-K-L-M. This sequence would have the advantages of delaying the opening of the Church and Castro Stations, with their associated additional costs and responsibilities, until the latest possible date. Similarly, as above (A), it would tend to minimize overloading of the system by transferring passengers. It would furthermore allow us to operate a relatively minimal LRV service (one or two lines) for as long as necessary to familiarize ourselves with the new vehicles and operating procedures; if only one Twin Peaks line began service in Phase 2 there would be pressure (both politically and physically because of West Portal and Castro transfers) to convert at least both the L and K. Also, an N-J-K-L-M sequence might allow MUNI to defer LRV revenue operations through West Portal (and Forest Hill?) reconstruction areas, perhaps until all but station finishing work is complete. Similarly, operation of the Twin Peaks rail lines could be deferred until completion of Embarcadero reconstruction, if necessary.

(2) N-K-L-M-J. This sequence addresses itself more to service requirements. It would allow our three most important rail lines, the N-JUDAH, K-INGLESIDE and L-TARAVAL, to operate with or without en-route coupling into the subway while the M-OCEAN VIEW and J-CHURCH are held until the Railway is fully prepared to commit all five lines to subway operation. Each line could operate on a 6-minute headway, with two-car trains as required (similar to the 75-second headway, no en-route coupling scenario suggested above). Since the combined subway headway would be only two minutes, the three lines could be operated without en-route coupling but with the existing Embarcadero turnaround facilities.

This sequence would, however, also allow us to begin en-route coupling at West Portal if desired.

The J-CHURCH would, with this approach, remain a surface operation until after all track replacement is complete. As opposed to the N-J-K-L-M sequence, which would mix LRVs with PCCs on Church Street, the N-K-L-M-J sequence would minimize mixing the higher-performance LRVs with lower performance PCCs on revenue lines. (Because of its common usage with the J,K,L and M, Church Street between Market and Seventeenth Streets will at any rate be MUNI's last rail replacement project.)

This sequence, with the K and L converting to MUNI METRO at the same time, would allow MUNI's two heaviest streetcar lines (the N and L)to commence subway operations at a relatively early date. Availability of both the K and L at West Portal and Castro Stations would ease the potential overloading problems cited previously. If a decision, however unpopular, is made to defer full operation until Embarcadero reconstruction is complete, this sequence would at least allow us to provide MUNI METRO service on our three heaviest rail lines.

3. SHORT-TERM RECONSTRUCTION AND EXPANSION

A. Background

The provision of a loop or other improved turn-around facilities at Embarcadero has now been under discussion for about as long as the Market Street Subway itself. A loop specifically has been recommended repeatedly both by MUNI staff and by various consultants, including LT Klauder and Associates (see Appendix B). One element of Embarcadero reconstruction has already taken place. On a "crash" basis, to allow construction prior to the inauguration of evening BART service last year, a limited amount of reconstruction through BART's Spear Street ventilation shafts was authorized and has already been completed. Since any MUNI extension trackage must pass <u>through</u> these ventilation shafts, these structural modifications would have had to be performed for <u>any</u> future extension, and could not be done concurrent with BART service.

Most recently, based on the operational constraints inherent in the present facilities and discussed earlier, and based also on the need for at least limited off-line vehicle storage, a request for funding was included as a $10 million line item in the System Improvement Program (SIP). A Request for Proposal for a first stage engineering contract to cover preparation of conceptual designs and estimation of construction costs has been undergoing UMTA review since February 1976, although it is now hoped to have a consultant contract underway by late Summer or early Fall this year. The comments which follow and subsequent discussion should form a basis for the consultants' analysis.

Completely apart from the issue of reconstruction at Embarcadero Station, a further short-term expansion of the MUNI METRO system has been proposed in the form of extension of the J-CHURCH line from the present 30th Street terminal via 30th Street and San Jose Avenue to a connection with the existing system at the Balboa Park Station/Metro Center site. The extension would be used for revenue service, but would also offer a significantly improved pull-in and pull-out route for the J-CHURCH and perhaps N-JUDAH, the original intent of the proposal's study.

The extension has been evaluated as part of the Planning-Operations-Marketing (POM) Study, and a final report on "New Track Linkage on the N-J Lines" is being prepared by the study consultant, Wilbur Smith and Associates. The consultant's efforts have been monitored and their findings reviewed extensively by MUNI staff, and are generally concurred in by the Municipal Railway's Planning Division. The J-extension will consequently not be reviewed in this paper, and the interested reader is referred directly to the Wilbur Smith report.

Mention should also be made of the extension of the M-OCEAN VIEW from Broad and Plymouth to the Metro Center. This is however now a committed project and construction is pending.

B. Alternatives and Opportunities for Embarcadero Reconstruction

Seven alternative concepts are represented schematically by Figure 2 on the following two pages, ranging from a "do-nothing" alternative (Concept A) through a low-investment revenue service extension (Concept G), which would both serve our short-term requirements and achieve a number of additional objectives as well.

It should be noted that any construction at Embarcadero should meet the following operational objectives and criteria as an absolute minimum:

---Significantly reduce train turn-around time from the present practical limit of about 2 minutes.

---Minimize labor costs by ensuring that "fall-back" crews (as explained below) are not required for efficient operations.

---Maximize vehicle storage facilities and provide space for at least one four-car train to be taken out of service.

---Ensure that possible future extension of the subway southward on an alignment parallel to Steuart Street and the Embarcadero is provided for by incorporating a conceptual extension directly into the designs prepared. Actual construction concurrent with the Embarcadero turn-around facilities should be specified as one available option in a longer term construction program.

The seven alternative concepts are as follows:

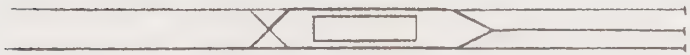
(1) Concept A: Present facilities. The present terminal arrangements at the Embarcadero Station, consisting of the two station tracks and a crossover west of the station, constitute a design common to rapid transit train operations functioning typically on a four-minute or greater headway. Occasionally, it has been applied with headways as brief as two minutes, although "fall-back" crews are also usual in that context.

It is a very restrictive arrangement for light rail operations such as MUNI intends. The physical layout of the station and tracks precludes train reversal at Embarcadero at less than a theoretical headway of about 80 seconds. Allowing a certain amount of slack, the minimum headway which could probably be realistically and reliably achieved is one on the order of 105 to 120 seconds. (See Appendix B).

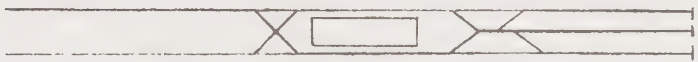
The allowance for slack time is critical because of the complexity of operations necessary to change ends and reverse train operation with the LRVs.

Figure 2.
EMBARCADERO TERMINAL RECONSTRUCTION
Alternative Schematic Designs

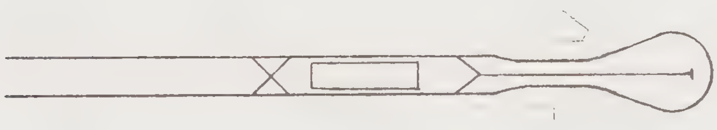
A. Present facilities



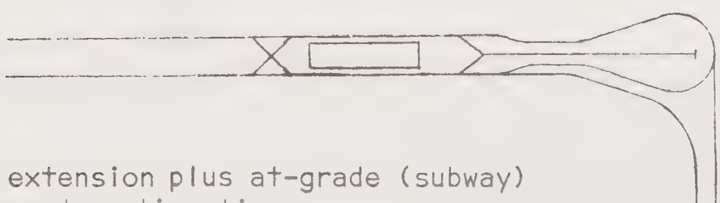
B. Three-track stub extension without crossovers



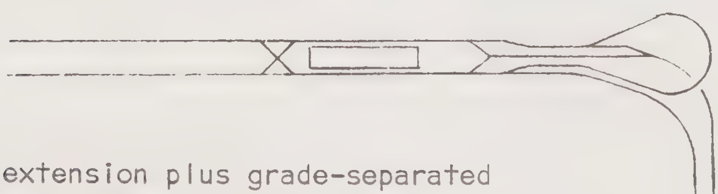
C. Three-track stub extension with crossovers



D. Loop extension with storage track



E. Loop extension plus at-grade (subway)
southward continuation



F. Loop extension plus grade-separated
southward subway continuation

Figure 2 (continued)
EMBARCADERO TERMINAL RECONSTRUCTION
Alternative Schematic Designs

G. Loop extension plus SP Depot, Third Street Corridor and Waterfront Rail Line Connector, with Mid-day Storage Facility (not to scale)

As explianed above, if trains cannot be turned at significantly less than a two-minute headway, as is the case with the present terminal, MUNI's five streetcar lines cannot all operate via the subway unless cars are run in trains with en-route, in-service coupling and all its remifications. A four-car train entering Embarcadero will include four operators, each of whom will have to deactivate their "front" cab controls, gather their transfers, schedules and other items, lock their cabs, go to the other end of the car, unlock the cabs, activate the controls, contact the lead car operator by radio to confirm his outbound route, and independently close his doors before the train is ready to depart. In addition, the operator on the lead car will, after confirming his train's make-up, have to manually enter this information on a push-button console at wayside. (A dispatcher will also be able to enter the information, but little time would be saved).

Not only are these operations complex, but there is the added risk of a component malfunction manifesting itself when operators change ends which at the Embarcadero Station would be precisely the worst time and place for an equipment manlfunction to be revealed. Furthermore, to maintain a two-minute headway and using both tracks at Embarcadero, these activities will all have to take place reliably in no more than $2\frac{1}{2}$ minutes--including the time consumed in actual loading and unloading of passengers.

Under these circumstances it will probably be necessary even with two-minute headways to schedule "fall-back" crews to assure smooth operation during peak hours. An operator would enter each LRV at Montgomery or Embarcadero and set up the west (outbound) cabs for operation. These operators would take trains on their outbound trips, while the inbound operators would leave the trains and "fall-back" to take over a subsequent train. Such "fall-back" crews are common on short-headway rapid transit stub terminal operations. Obviously labor costs would be increased with such an arrangement.

In addition to the need for en-route coupling, the complex terminal procedures, increased labor costs, and the added likelihood of a malfunction when changing ends, an additional shortcoming of the existing Embarcadero Station is its lack of any fully useable vehicle storage facilities. Storage sufficient to accomodate at least a four-car train is vital to allow a "dead" train to be taken out of service.

In addition, any mid-day storage which can be provided for up to about 30 LRVs would allow a significant reduction in labor and other operating costs associated with mid-day pull-in and pull-out movements.

From a standpoint of operations, reconstruction of MUNI's Embarcadero terminal facilities is vitally important, and should already have been begun.

(2) Concept B: Three-track stub terminal without crossovers. As illustrated, this is the simplest form of extension, and was first described in a feasibility study assembled by Foster Engineering, Inc., in February 1975. MUNI's tracks would be extended eastward past BART's Spear Street ventilation shafts. The first portion of the extension would be constructed by tunneling; the eastmost portion would be constructed by cut-and-cover methods under the eastmost section of Market Street and under Justin Herman Plaza. Each tail track would be sufficiently long to accommodate a four-car train.

The principal drawback of this plan is that with the track arrangement as shown, trains could be reversed and switched from what would become the eastbound to the westbound Embarcadero Station track only by using the single center track of the extension.

Under this arrangement, however, with only the one track available to turn trains, the capacity of the terminal in terms of the number of trains which could be reversed in each hour, would not be improved and in fact would be reduced. Consequently, this arrangement does not meet MUNI's needs and should not be considered further.

(3) Concept C: Three-track stub terminal with crossovers. The addition of crossovers on the tail tracks, as shown in the schematic drawings as Concept C, would mitigate the above problem by allowing switching movements to utilize any or all of the three tracks. However, if constructed in the same space as proposed for Concept B, the length of the tracks beyond the switches would now no longer be sufficient to accomodate four-car trains.

If the February 1975 Foster Engineering study is correct, simple extension of the tracks still further eastward on a straight alignment would probably not be feasible, because the tracks would have to cross the Embarcadero sea-wall and would essentially extend out into the mud of the Bay. Costs would almost certainly be prohibitive.

The only way Concept C could be made useful would probably be to curve the structure southward, much on the alignment shown for possible extensions in Concepts E, F and G.

However, even so, on short headways switching moves would be quite complex, and it is not yet certain to what degree the minimum associated trunk headways could be reduced. Furthermore, the added switching times per train, even if allowing somewhat reduced headways, would result in increased labor costs, similar to those associated with "fall-back" crews.

In summary, while a variation on Concept C represents the only possibly viable version of an improved stub terminal layout, it will probably still leave many of the problems associated with the present layout unresolved.

(4) <u>Concept D: Loop extension with storage track</u>.
From an operational standpoint, a loop turnaround is unquestionably superior in terms of reliability and ease of operation, particularly on a short-headway schedule. A loop would completely eliminate the need to change ends, thereby eliminating most of the potential sources of delay, as well as any need for extra crews. Inbound operators would have no need to move to different control positions to turn a train. Furthermore, a loop terminal would allow Market Street subway headways to be governed by line capacity, not by terminal capacity, since LRVs would run through the Embarcadero Station much as PCCs loop past their Trans Bay Terminal stop.

RAPTRAN simulation tests of a hypothetical loop suggest that, including 15-second dwell periods both when arriving and departing Embarcadero Station, the time required to traverse a loop is about two minutes--or less than the total dwell associated with the existing Embarcadero terminal facility. Hence a loop is likely to minimize time and labor costs associated with train reversal among the four alternatives so far presented.

Concept D as shown in the schematic diagram includes a center storage track sufficient to accommodate a four-car train, either for mid-day storage or to take up to a four-car unit out of service in event of a breakdown. Both this stub track and the crossover west of the station are also available to be used to resequence trains as necessary. For example, a train could be held on the stub track while another train passes it on the loop.

This proposal was also included in the February 1975 preliminary engineering study, and was found feasible. At that time it was estimated that either the Concept D loop or the Concept B stub arrangement could be constructed for between $8 and $12 million.

(5) Concept E: Loop extension with provision for at-grade (subway) southward continuation. As suggested earlier, it is essential that any Embarcadero track extension not preclude subsequent further extensions of trackage, principally in the southward direction. There are three likely corridors to which such an extension would connect, either for revenue through-service or to connect such lines to the basic MUNI METRO system. The most immediate potential connection would be to the Belt Line Railroad trackage, linking up to the proposed Embarcadero rail service. This is elaborated on as Concept G, below. A future connection to a Third Street or Bayshore Corridor line must also be retained as an option, as must a possible connection via Mission Street or Howard and Third Streets to a Geary Corridor line, as was recommended by the consultant to the 1971 study of that corridor. However, since any such line has been rejected as city policy, it is the former two opportunities which should be stressed.

The design as sketched is a minimum cost alignment, based on single-level subway construction. It should be noted, however, that the switch for the southward turn-off is located as close to the Embarcadero Station as possible, with the return track connecting approximately mid-way around the loop. The intent of this arrangement, which should be stressed, is to allow a four-car train a position in which to wait between these points, without fouling either track. In-service train movements to and from a southward extension should not be delayed by trains being turned. It is the trains being turned, which at that point will not be carrying passengers, which should be held for in-service continuing trains if need be.

A secondary benefit of constructing this first portion of an extension track lead now would be to provide additional interim storage at Embarcadero for at least one additional four-car train.

At the very least, it would be desirable for initial Embarcadero turnaround reconstruction to include sufficient provisions for such extensions to allow their subsequent construction without disrupting loop operations. The one further extension which may be justifiable at this time is discussed, as already mentioned, as Concept G below.

(6) Concept F: Loop extension with provision for a grade-separated southward subway continuation. This alternative is a variation of Concept E intended to improve operational efficiency somewhat by using a grade-separated subway crossing to keep the southward extension tracks separated from the turnaround loop itself. This would be similar to the subway junction at Market Street and Duboce Avenue. Since the loop would be built at close to minimum radius curvature, this alternative alignment would allow a smoother curve and hence a smoother ride as well as a higher operating speed for trains coming north from the extension when approaching Embarcadero. Connecting the stub track of Concept E to this trackage as illustrated is optional but would also enhance the flexibility of the Embarcadero Station facilities.

While Concept F is a relatively minor variation on the preceding proposal, it offers the best long-term alignment, and a decision between "E" and "F" should govern the final design of a loop, even if only as much as is illustrated as Concept D is committed at this time. Obviously, as a first step a feasibility study must be conducted, as it is possible that proximity to the BART Transbay Tube may make it impossible to construct a loop on two levels at all.

(7) Concept G: Loop extension with connection to Embarcadero surface tracks. This proposal, with the connections and features illustrated in the schematic design, offers the opportunity for a low investment extension to the MUNI METRO system. Upon examination, such an extension could resolve a surprisingly large number of problems both confronting MUNI today and confronting the City and Bay Region with respect to several proposed and adopted transportation plans and policies.

The basic features of such an extension would begin with the proposals described as Concepts E and F. ("E" is illustrated on the Concept G sketch; either "E" or "F" could be incorporated in a final design.) The tracks would be brought to the surface via a portal to be constructed either at the present MUNI "Ferry" terminal site or nearby, or along the Embarcadero right-of-way south of Mission Street. As shown, it would connect with the tracks proposed for the Embarcadero rail line and continue south to the Southern Pacific Depot, where a limited storage facility could be built adjacent to or under the I-280 Freeway.

The opportunities such a plan affords include the following:

---Provide MUNI METRO service to the SP Depot, by through-routing one or more lines over the extension. This would ease Embarcadero Station operations by reducing the number of trains turned at Embarcadero.

---Various sites near the SP Depot, such as under the 1-280 Freeway, seem to be available for provision of a modest storage facility for mid-day storage of LRVs. Such a facility could essentially eliminate the labor and operating costs associated with mid-day pull-ins and pull-outs. It might also be used for overnight storage of N-JUDAH cars, similarly resulting in reduced pull-in and pull-out costs.

---An Embarcadero rail service, using upgraded Belt Line Railroad facilities, was first proposed in 1974 by G.P. Cauthen, in a report titled "A Surface Rail System for the San Francisco Waterfront." The line as proposed would extend from the SP Depot along the Waterfront to Fisherman's Wharf and perhaps to Fort Mason. It would provide collection and distribution for the SP Depot and also collection and distribution for peripheral parking facilities located near the 1-280 Freeway, as well as serving the obvious recreational access function.

The Embarcadero rail service proposal has been provided for in plans for the Northeastern Waterfront, and is consistent with recommendations of the Planning Advisory Committee for the Northern Waterfront, and with objectives adopted by the City Planning Commission.

The Concept G proposal would provide a physical connection, via the subway, between the Embarcadero rail line and the MUNI's principal rail vehicle maintenance and storage base at Balboa Park.

---The Peninsula Transit Alternatives Project called for a major upgrading of Westbay Corridor service to include improved access to downtown San Francisco destinations for Southern Pacific rail service passengers. The extension of MUNI METRO would provide a high-speed, high-capacity link from the SP Depot to the Financial District, Civic Center and other San Francisco points. Operating cost offsets could be achieved by reductions in present surface bus operations such as the 40-COMMUTER and 80-GATEWAY EXPRESS.

---One of the more interesting options to emerge from POM Study work on the proposed "J"-extension concerns the through-routing of the extended J-CHURCH with the M-OCEAN VIEW. If through-routed as two one-way loops, it would become necessary to provide a layover point at the inner terminal where schedule recovery time could be taken. The intensity of operations at Embarcadero precludes regularly scheduling layovers at that point. Extending the J-M trips to the SP Depot, however, would very conveniently allow terminal layovers to be taken there.

---From its terminal at Fourth and Townsend, the proposal would allow a low-cost "jumping off point" for a future Third Street or Bayshore Corridor rail line, via either Fourth and Third Streets or via the Southern Pacific right-of-way.

C. <u>Funding</u>

The first question which obviously arises with respect to the preceding discussions concerns funding. At the outset, it should be noted that beyond the UMTA and local funds already committed to Embarcadero reconstruction through the System Improvement Program, it appears likely that any of the concepts enumerated here including Concept G could be built without additional encumberance on San Francisco taxpayers, now or in the future.

Specifically, at least two sources of existing non-local tax and non-bond funding are available which could be committed to this project and may not be available for other MUNI needs. These sources, which could be used as local match against 80% Federal funding, are the (Proposition 5) Fixed Guideway Reserve Fund and TDA funds.

It appears that the Fixed Guideway Reserve fund could provide San Francisco $2.5 million between FY 1977-78 and FY 1981-82, the period to be covered by the current Five-Year Plan. This is over and above a $1.0 million amount required as local match to the $5.0 million cost of the M-line rerailing and extension projects, and can <u>only</u> be used for fixed-rail capital projects.

TDA funds are less certain in magnitude, but have provided upwards of $4 million annually in previous years. At this continued level, $20 million would be available over FY 1977-78 to FY 1981-82, of which only $8 million has been committed to currently programmed capital items.

This leaves $12 million in probable TDA funds and $2.5 million in Fixed Guideway Reserve funds, or $14.5 million which could be used as the local share for Federal match grant purposes. On an 80-20 basis, this could cover $72.5 million in currently unprogrammed capital items.

Although no cost estimates have yet been made, a third of this amount should be more than adequate to cover the amount by which even Concept G exceeds funds already committed to the Embarcadero extension.

4. RECOMMENDATIONS

What follows is proposed as a strategy for phasing into full MUNI METRO service, based on the discussions above. After review by MUNI staff and others and in particular the representatives serving as the MUNI METRO Planning "Task Force," it is intended that these recommendations, along with any modifications made during review, be incorporated into the Five Year Plan as the Railway's MUNI METRO Operations and Facilities Plan.

A. Phase 1: Now through MUNI METRO Start-up.

(1) N-Judah service. Efforts should continue to be geared toward initiation of MUNI METRO service over the N-line, using a schedule based approximately on present headways, resulting in a car-for-car substitution of service. Such a schedule would provide a capacity increase of over 50%, and would require approximately 25 LRVs, based in part on the draft schedule worked out two years ago. A stand-by schedule to respond to excess demand for service should also be prepared, based on 2½ minute peak headways. This would require an additional 5 or so LRVs. Until MUNI staff have throughly familiarized themselves with MUNI METRO operation, no attempt should be made to schedule service involving any en-route coupling, or operating at subway headways of less than 2½ minutes. N-JUDAH service will require staffing of the Embarcadero, Montgomery, Powell, Civic Center and Van Ness Stations, but not Church or Castro.

Consideration might be given to initiating service at first on a Monday-Friday and/or 6 a.m.-to-8 p.m. only basis, with PCC or bus service at other times for a few weeks or a few months. This would conserve costs associated with station agents as well as allowing weekend or evening use of the cars and subway for intensive testing and training.

(2) Embarcadero Station. Work on engineering design and subsequent reconstruction of facilities at Embarcadero should be expedited so as to get underway at the earliest possible time. In concurrance with recommendations by MUNI staff members as well as the analyses summarized in this paper, the design should include a turnaround loop, Minimum construction should conform to design Concepts E and F described earlier, but serious consideration should be given to carrying construction through what is presented above as Concept G.

Construction at this time to the limits schematically indicated by Figure 3 would not only conform to Concept E, but would also provide maximum storage capability at Embarcadero at the earliest possible time and at minimum cost. As illustrated, 2 four-car storage tracks could be provided.

(3) Coupling. No final decision with respect to en-route, in-service coupling needs to be made prior to the inauguration of service as recommended above. However, extensive testing should commence as soon as LRVs are on the property, and a final decision whether to attempt en-route coupling in Phase II must be committed no later then one month after inauguration of N-JUDAH MUNI METRO service. This is to allow sufficient time for training and schedule preparation for Phase II service, which should follow Phase I start-up by 4 to 6 months, if possible.

It is also recommended that the curved portion of the railings on the Judah Street islands be removed or modified, so that passengers can step on and off the ends of the platforms. This will then allow multiple-car operation at MUNI's option should it prove necessary or desirable, though again no firm decision needs be made prior to start-up. Initial service should be strictly on a single-car basis.

(4) J-extension. Design studies and efforts to secure funding and both popular and political support should be undertaken as soon as possible.

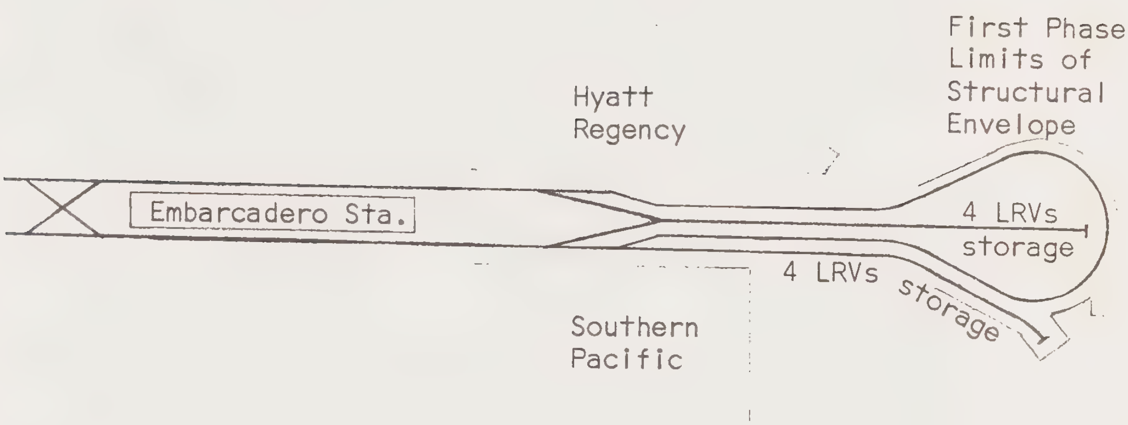
(5) K-INGLESIDE and M-OCEAN VIEW Extensions.
Extensions of both these lines to the Balboa Park Station are committed projects. An estimate should be made and kept current as to when these extensions may be expected to be available for service. Subject to the availability of PCCs (and remembering that N-JUDAH LRV start-up will free about 26 cars), consideration should be given to modifying the K and M extensions for PCC operation if PCC service could thereby be inaugurated six months to a year or more earlier than if such service awaited use of LRVs on those lines.

It should be remembered that, by all present indications, operating K-INGLESIDE PCCs to the Balboa Park Station will require only the installation of about 6 wire frogs by Hetch Hetchy crews.

B. Phase II: MUNI METRO Service on three lines.

(1) Coupling. Based on the decisions made during Phase I, Phase II service could allow but does not require MUNI to begin en-route, in-service coupling on a limited basis. However, schedules for Phase II will have to be based on either en-route coupling or operation of fixed two-car trains at some times on some lines, assuming reconstruction of terminal facilities at Embarcadero Station has not yet been completed.

Figure 3.
RECOMMENDED MINIMAL FIRST PHASE EMBARCADERO TERMINAL RECONSTRUCTION
Schematic Design



A final decision on en-route coupling under Phase III must be made during Phase II.

(2) K-INGLESIDE and L-TARAVAL. Service on the K and L lines should be integrated with N-JUDAH service to provide MUNI METRO service on three lines as the basis for Phase II. Assuming reconstruction at Embarcadero is not complete, subway trunk headways will be limited to 2 minutes. This will require either two-car trains during peak periods on all N and some L and K runs with each line on a 6-minute average headway, or 2 to 3-minute headways on the branches with en-route coupling for about 50% of all peak-period K, L and N trips.

Inauguration of K and L MUNI METRO service will require staffing the Church and Castro Stations. It is also recommended that Phase II service not be initiated until after West Portal Station is complete, although under present schedules this should not pose any probelms. Phase II should also await availability of the full MUNI METRO radio communications system and new central control facilities, although, while desirable, these should not be considered essential for Phase I. If possible, Forest Hill Station should be closed for rebuilding no later than the Phase II start-up date.

(3) N-JUDAH. It is likely that we will be in at least Phase II operations before we are ready to replace the two blocks of track on Duboce Avenue between Church Street and the Sunset Tunnel. Work on this short segment should be restricted to weekends and evenings in such a way that LRV operation over portable cross-overs can be avoided. Substitution bus service should be operated as necessary during these periods.

(4) M-OCEAN VIEW. To avoid interference with LRVs on the K and L and yet avoid the complexity of converting the M to subway operation at the same time, the M should be operated as a temporary shuttle to West Portal. Through operation of PCCs to downtown as at present would be possible, but would make little sense as most passengers could be expected to transfer at West Portal to the LRVs anyway, because of the likly 20-minute time savings between West Portal and Embarcadero.

The shuttle could, however, be operated with LRVs, as cars could be reversed using the cross-over just east of the West Portal Station, or the cross-over on Ulloa Street. Alternately, the shuttle could be operated with buses. The former would be preferable, in terms of both service and introducing LRVs to the public, provided all wire and trackwork on the M-line has been completed by this time, but would require careful coordination with K-INGLESIDE and L-TARAVAL operations.

(5) J-CHURCH. It should be obvious that this scenario would imply that only the J-line would still operate with PCCs when Phase II is initiated, and only the J-line would operate on the surface of Market Street. This will then allow the scheduling of track replacement on Church Street between Market and Eighteenth Streets. With only the one line in operation on Church Street, use of PCCs over temporary crossovers will be very straightforward with minimal inconvenience to passengers.

As constrasted with the M-line, both the passenger volumes on the J-CHURCH and the proximity to downtown would argue against a forced transfer at Market Street from an interim J-CHURCH shuttle service.

(6) Market Street trolley coach services. MUNI service to and from the Transbay Terminal is now provided by the five Market Street streetcar routes. While the removal of one line in Phase I (the N-JUDAH) should not cause any adverse difficulties for our passengers, substitute service must be provided no later than Phase II as defined here; the J-CHURCH and 38-GEARY alone will probably be inadequate, and without the J-CHURCH such would definitely be the case.

Presently, approximately 760 AC Transit passengers transfer to MUNI streetcars at the Terminal in the peak hour.* Both POM Study and Planning Division staff recommendations suggest routing several present Market (and Sutter) Street TC lines to the Transbay Terminal concurrent with introduction of MUNI METRO operations, and such facilities must then be in place before Phase II operations begin. The following comments are from the September 1976 Final Report of the Bay Area Transportation Terminal Study (p.3-35):

> Approximately 25% of AC Transit patrons use MUNI in San Francisco.
>
> When the MUNI METRO begins operations underground in Market Street, the streetcar terminal point will be moved from Transbay Terminal to the Embarcadero Station The J, K, L, M and N streetcars will no longer turn around at Transbay Terminal.
>
> MUNI is now planning to replace this service by moving the terminal of the 3 (Jackson), 5 (McAllister), and 6 (Masonic) trolley lines to Transbay Terminal. This change, replacing the present streetcars with the trolley lines, is most important to successful operation of the terminal.

---

*Barton Aschman Associates Working Paper #3, Table A-2, Bay Area Transportation Terminal Study. This is 1973 data; however, AC Transit's present transbay ridership has now returned to approximately pre-BART levels, so that this data can still reasonably be assumed current.

Present indications are that the planned replacement service will be a reasonable service substitution for the streetcars. The trip distribution on the new service is actually better than that of the present service.

This replacement service is important. If for any reason sufficient interface with MUNI is not provided, lack of trip end distribution system (i.e., MUNI) in Downtown San Francisco could become a critical issue to the Transbay Terminal Program.

It should be noted that work on such overhead structures as are required could easily become critical to timing Phase II. While Hetch Hetchy Water and Power, who have responsibility for MUNI's overhead lines, have already been appraised of this need, experience suggests that time is of the essence.

C. Phase III: Full MUNI METRO Service.

(1) Embarcadero Station. As a basic parameter for scheduling the inauguration of full MUNI METRO service on all five lines, it would be both advisable, and, if MUNI seeks to avoid en-route coupling operations, it will be absolutely necessary, to complete construction of the revised Embarcadero terminal facilities before moving into Phase III. The headways and operating strategies, advantages, opportunities, and increased flexibility and reliability afforded, have all been discussed previously on pages 3-7 and 11-21. Obviously the coupling issue is crucial in any event.

(2) M-OCEAN VIEW. Given reconstruction of track and electrical power facilities, both of which should be completed well in advance of Phase III, the only constraints on full MUNI METRO service on the M-line will be completion of Embarcadero Station construction and, if we do opt for en-route, in-service coupling, MUNI's readiness to commit ourselves to coupling on an all-day and short peak-headway basis. It should be reiterated again as discussed above, that en-route coupling can be avoided.

(3) J-CHURCH. Physically, the J-line would be available for MUNI METRO operation as soon as track and wire reconstruction between Market and Eighteenth Streets is complete. However, again on the basis of Embarcadero reconstruction and the implications of the coupling issue, it may be necessary to retain PCC operation until a rebuilt Embarcadero facility is available. Again, and as on the M-line, en-route coupling can be avoided at MUNI's option, given Embarcadero reconstruction.

It is also possible that by the time MUNI is preparing for Phase III operations, construction of the J-extension will be underway or at least committed; hopefully, that will be the case. Operation of an extended J route also will require an additional 3 to 8 LRVs. One further point to note is that an operating strategy based on en-route coupling will demand total operational compatibility with the Boeing LRVs of any additional vehicle procurements; a strategy not depending on en-route coupling would also allow non-compatible equipment without any penalty. The converse is also true: if Boeing for any reason does not continue production of the present LRV, MUNI may find itself in a position of not being able to procure any affordable additional equipment which would allow en-route coupling to take place.

These constraints apply not only to the J-CHURCH extension, which would require some additional vehicles for revenue service, but over the life of the Boeing equipment to any other expansion of MUNI METRO service which would tie in to our five basic routes.

Appendix A:

Municipal Railway Schedules

1930 and as Proposed for MUNI METRO

MUNICIPAL RAILWAY OF SAN FRANCISCO

ROUTES AND SCHEDULES

June 1, 1930 Subject to Change Without Notice

LINE "J"—CHURCH STREET

Brown Dash Sign

From the Ferries, via Market and Church Streets to 30th Street.

Time of trip: 26 Minutes

	Week Days	Sundays
First car from 30th Street	5:12 A.M.	5:20 A.M.
Last car from 30th Street	2:00 A.M.	2:00 A.M.
First car from Ferries	5:33 A.M.	5:43 A.M.
Last car from Ferries	2:23 A.M.	2:23 A.M.

OWL SERVICE

From 30th Street to Ferries: 2:20 A. M. and half hourly thereafter to 4:50 A. M.

From Ferries to 30th Street: 2:53 A. M. and half hourly thereafter to 5:23 A. M.

Transfer connections with all intersecting Municipal Railway lines.

LINE "K"—MARKET STREET

Green Dash Sign

From the Ferries, via Market St., Twin Peaks Tunnel, Junipero Serra Blvd., Ocean and Brighton Avenues to Grafton Avenue.

Time of trip: 36 Minutes

	Week Days	Sundays
First car from Grafton Avenue	5:23 A.M.	5:36½ A.M.
Last car from Grafton Ave. (to Ferries)	2:03 A.M.	2:03 A.M.
First car from Ferries	5:53 A.M.	6:09 A.M.
Last car from Ferries	2:35 A.M.	2:35 A.M.

OWL SERVICE

From Grafton Avenue to Market Street and Van Ness Avenue: 3:09, 4:09, 5:03 A. M.

From Market Street and Van Ness Avenue to Grafton Avenue: 3:33, 4:33, 5:30 A. M.

Transfers to and connects with inbound and outbound Line "J" Owl Cars to and from Ferries, and North and Southbound Line "H" Owl Cars at Market Street and Van Ness Avenue.

Transfer connections with all intersecting Municipal Railway lines, and to OUTBOUND Market Street Railway Line No. "12", from OUTBOUND Line "K", and from INBOUND Market Street Railway Line No. "12" to INBOUND Line "K" Cars at St. Francis Circle and Sloat Boulevard, and with Municipal Bus line (Route 1) at Forest Hill Station.

LINE "L"—TARAVAL STREET

Yellow and Green Dash Sign

From the Ferries, via Market St., Twin Peaks Tunnel, Ulloa St., 15th Avenue and Taraval Street to Great Highway and Ocean Beach.

Time of trip: 36½ Minutes

	Week Days	Sundays
First car from Beach	5:39½ A.M.	5:31½ A.M.
Last car from Beach (to Ferries)	1:26 A.M.	1:26 A.M.
First car from Ferries	6:14 A.M.	6:05 A.M.
Last car from Ferries	1:58 A.M.	1:58 A.M.

OWL SERVICE

From Beach to Market Street and Van Ness Avenue: 2:35, 3:35, 4:35 A. M.

From Market Street and Van Ness Avenue to Beach: 3:03, 4:03, 5:03 A. M.

Transfers to and connects with inbound and outbound Line "J" Owl Cars to and from Ferries, and North and Southbound Line "H" Owl Cars at Market Street and Van Ness Avenue.

Transfer connections with all intersecting Municipal Railway lines, and with Municipal Bus lines (Route 1) at Forest Hill Station and (Route 2) at the Beach.

LINE "M"—OCEAN VIEW

From Junipero Serra Boulevard and St. Francis Circle, via West Portal Ave., 19th Avenue Extension, Worcester, Randolph, Orizaba and Broad Streets to Plymouth Avenue.

Time of trip: 10 Minutes

	Week Days	Sundays
First car from Plymouth Avenue	5:30 A.M.	6:19 A.M.
Last car from Plymouth Avenue	12:48 A.M.	12:48 A.M.
First car from St. Francis Circle	5:42 A.M.	6:31 A.M.
Last car from St. Francis Circle	12:37 A.M.	12:37 A.M.

Transfer connections with Line "K" at St. Francis Circle.

LINE "N"—JUDAH STREET

Orange Dash Sign

From the Ferries, via Market St., Duboce Ave., Sunset Tunnel, Carl St., Arguello Blvd., Irving St., 9th Ave. and Judah St. to Great Highway and Ocean Beach.

Time of trip: 36 Minutes

	Week Days	Sundays
First car from Ocean-Beach	5:26 A.M.	5:41 A.M.
Last car from Ocean-Beach (to Ferries)	12:51 A.M.	12:51 A.M.
Last car from Ocean-Beach (to Market & 11th Sts.)	1:51 A.M.	1:51 A.M.
First car from Ferries	5:55 A.M.	6:13 A.M.
Last car from Ferries	1:20 A.M.	1:20 A.M.

Transfer connections with all intersecting Municipal Railway lines, and with Municipal Bus lines (Route 1) at 9th Avenue and Irving Street, and (Route 2) at 48th Avenue and Judah Street.

Appendix B:

Selected Correspondence and Memoranda on Embarcadero Terminal Facilities and the Issue of Coupling

COMPARISON OF SCHEDULES

"The more things change, the more things stay the same."

Trip Times--Minutes

	1930	1977 (Peak)	MUNI METRO
J-CHURCH	26	35-40½	17-21½
K-INGLESIDE	36	46½-52	24
L-TARAVAL	36½	52½-55½	30-34
M-OCEAN VIEW	10 *	13 *	13 *
N-JUDAH	36	47½-49½	33½-35

Except as noted, 1930 running times are from "the Ferries" to the outer terminals of each line, 1977 times are from the Transbay Terminal, and MUNI METRO times are from Embarcadero Station.

* - M line times are from St.Francis Circle to Broad and Plymouth only.

TRANSIT IMPROVEMENT PROGRAM

August 12, 1974

LRV - Door Controls

L. T. Klauder & Associates
Philadelphia National Bank Building
Philadelphia, Pennsylvania 19107

Attention: Mr. R. D. Touton, Jr.

Gentlemen:

We have begun studies to develop subway operating procedures and a problem arises with the reversing of vehicles at Embarcadero Station. It will be an inconvenience to patrons if the lights go out in the vehicle during the period while the operator is moving from one console to the other.

Please give me your interpretation of the reversing procedure at Embarcadero. In addition to the lights we are concerned about the possibility that the doors will close as the operator puts the front console in layup.

I would also like to know whether both transfer switches on a vehicle can be in the standby mode.

Very truly yours,

THOMAS A. MULLANEY
Program Manager - LRV

TAM:rf

cc: GDuarte
PStraus
RBei
TMullaney
MCohn
TIPFile - LRV #6 MR/LTK

LOUIS T. KLAUDER AND ASSOCIATES
CONSULTING ENGINEERS
PHILADELPHIA NATIONAL BANK BUILDING
PHILADELPHIA, PA. 19107

LOUIS T. KLAUDER
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DAVID H. CUSHWA
LOUIS T. KLAUDER, JR
GEORGE R. BEETLE
ROBERT G. STACY
ALBERT N. FERRARI

JOHN W. IRVIN
ROBERT M. PRICE
HENRY T. RAUDENBUSH
RUSH D. TOUTON, JR.
RICHARD F. MILLER
ROBERT B. WATSON

(215) 563-2570
TELEX 83-4793

August 15, 1974
File No. 1128/1.1.0

Transit Improvement Program

Mr. T. A. Mullaney
LRV Program Manager
Transit Improvement Program
San Francisco Municipal Railway
949 Presidio Avenue Room 150
San Francisco, California 94115

Subject: LRV - Coupling Procedures

Reference: Your Letter of July 31, 1974

Dear Mr. Mullaney:

We are disappointed that your Operation Supervisors are skeptical that the LRV coupling operation can be accomplished efficiently and safely. The entire success of the LRV program hinges on making use of this valuable feature. However, we also recognize that this technique is new to Muni and that safety of the passengers is of paramount concern. We hope the following comments will be helpful.

There is an element of risk in the operation of any transit vehicle; motor-coach, trolley bus or LRV. This can result from unconscientious drivers, equipment defects or external traffic conditions. A degree of judgment must be exercised in the use of any safety-related device. For example, rapid application of any vehicle's braking system can result in passenger fall-downs as is evidenced by your posted notice "Hold on Sudden Stops Sometimes Necessary". The intent, of course, is to minimize injury or to put it more bluntly: It is preferable to have a passenger break an arm rather than kill him in an emergency.

The point of this preface is that the advantages and disadvantages of using any device must be carefully evaluated and the most effective trade-off made. It is our feeling that the advantages of using the coupling system far outweigh any possible disadvantages.

Your present surface operation of all types of vehicles during rush hour results in lines of vehicles repeatedly stopping within about six inches of each other. An occasional mishap does occur, but the relatively low speed of these unfortunate impacts seldom results in serious injury to the passengers. Rather than aggravating this condition, the addition and use of the couplers will actually significantly minimize the number of these occurrences for the following reasons:

Each LRV coupler incorporates a graduated energy absorption device on the shank that is not found on any of your other vehicles. Also, the draft gear anchorage (car body connection) is specially designed to provide energy absorption through deformation of resilient elements. Beyond that point, the anti-climber and first few feet of the vehicle are also designed to absorb energy during a more severe impact to a degree that is far better than any of your existing vehicles.

It should also be noted that the LRV design is far more advanced than the very rudimentary cushioning features found on existing coupler equipped PCC cars such as MBTA, Shaker Heights and Toronto.

With these LRV features, coupling impacts of up to two mph (relative motion) can be absorbed without damage to the car or any discomfort to the passengers, of up to ten mph with only minimal damage to the car (i.e., pre-planned, replaceable coupler shank) and minimal injury or fall-downs to the passengers, and up to fifteen mph with easily repaired damage to the car and minor injuries or fall-downs to the passengers. This, of course, is better than existing transit vehicles and much better than private automobiles.

Present individual operation of vehicles results in the frequent close stopping described above. By coupling as many as four LRVs together in a train at a single controlled location, random and continuing close stops during a trip to Embarcadero are eliminated as is the great possibility of concomitant low speed collisions and hard brake applications. With coupled trains the normal operating headway will be increased such that a train will clear a station before the following train

enters it compared to the need to close up at stations when operating single cars. This is important because your cab signal system allows cars to proceed at ten mph on a red indication. Only at interlockings do you have an absolute stop by virtue of a red wayside signal which takes precedence.

Coupling cars while carrying passengers has been and is an accepted operating procedure. In this country high speed electric interurban lines have historically done this to provide the same kind of operating efficiencies in serving diverting routes as Muni is planning. Today, the suburban Philadelphia routes of SEPTA and the Toronto Transportation Commission provide examples of this kind of operation. Further, the world over, railroads and light railways couple sleeping and dining cars as well as coaches while carrying passengers.

Muni's subway will provide off street areas for selective coupling of cars which will avoid interference with surface traffic and make for an orderly coupling procedure. This procedure will be to make a safety stop a short distance from the car in front, start up and maintain the low coupling speed necessary (approximately one mph) to the point of actually coupling. The Duboce Portal area has a further advantage in that the coupling location is on a descending grade. This will make for a smoother and more safe coupling procedure due to the more precise low speed control available to car operators by using the friction brake alone (rather than the necessary power-coast-brake cycle used for level coupling). The validity of this can be verified by a simple test in one's own private automobile. From a dead stop it is easier to start and maintain a very low speed on a descending grade using the brakes rather than on the level or an ascending grade using the accelerator (neglecting automatic transmission effects).

The coupler itself will lead to better coupling with less coupling speed than is usual with previous transit vehicles due to the minimized coupling force necessary resulting from its simple, modern and yet well proven design. This German coupler is specifically designed to couple cars in revenue service with passengers on board and an identical coupler can be seen operating in this type of light rail service in Munich and elsewhere.

In summary, the risk of collisions with vehicles in close proximity exists whether or not they perform a coupling operation. Therefore, a controlled coupling operation such as Muni is planning will provide additional spacing between groups of vehicles with a significant improvement in overall vehicle and passenger safety - as well as a dramatic improvement in service efficiency.

Sincerely yours,

LOUIS T. KLAUDER AND ASSOCIATES

R. D. Touton, Jr.

RDT:pw

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(215) 563-2570
TELEX 83-4783

August 19, 1974
File No. 1128/5.4.0

Transit Improvement Program
Municipal Railway
RECEIVED
AUG 22 1974

Mr. T. A. Mullaney
LRV Program Manager
Transit Improvement Program
San Francisco Municipal Railway
949 Presidio Avenue   Room 150
San Francisco, California 94115

Subject: LRV Door Controls
Muni Letter of August 12, 1974

Dear Mr. Mullaney:

Changing car ends (the operator moving from one console of a car to the other) requires placing the first console switch in layup, walking to the other end and placing that switch in either standby or operate (depending on whether it becomes a lead car or not). If one man does this, the car lights will indeed go out while he is between consoles. However, with a relay man one console may be placed in standby or operate before the other is placed in layup.

The car doors will not automatically shut as the operator places a console in layup (or back to operate/standby) but he may well wish to shut the doors before changing ends to keep passengers off of the car during this procedure (this is now done at the end of the J-Church line). In any case, although two consoles may be placed in standby in one car the car (or train) cannot operate unless the console of a car is in layup and the other console of the same car is in either standby or operate.

One further note, when changing ends at Embarcadero the operator must check to be sure the step switch is in high position in the new console and must remember that if ends are changed on the surface this switch must be in low position (the steps will automatically assume a left-high right-low situation with the step switch in the low position).

We realize that there are complexities involved in these operations but it was decided by Muni early in the program that extra trainline functions (door control, light control, train energization, etc.) were not worth the increased car complexity and cost. Further, as we recommended several times, the capital expenditure made for a loop at Embarcadero would have eliminated many of these operating problems and car complexities.

Sincerely yours,

LOUIS T. KLAUDER AND ASSOCIATES

W. E. Stinger Jr.

W. E. Stinger, Jr.

WES:pw

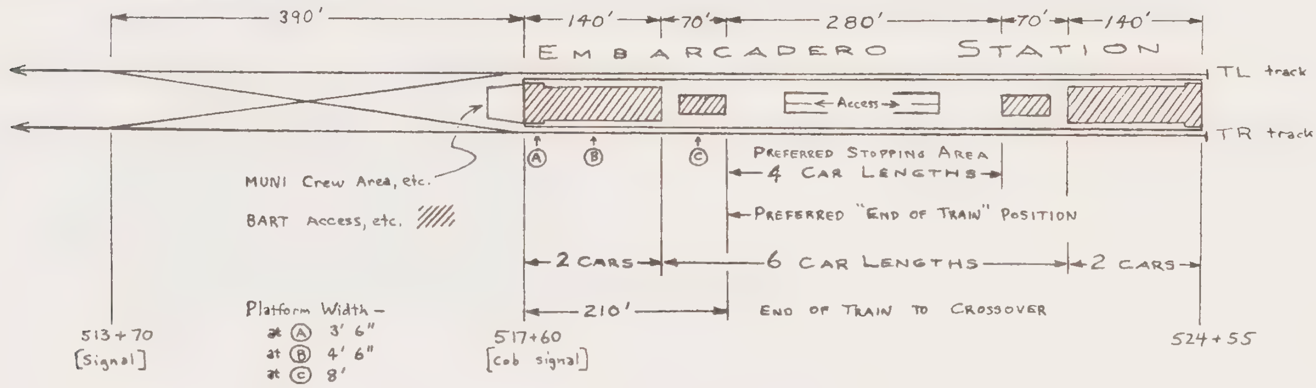
cc: T. J. Murray
Z. A. Stacno

OPERATIONS: EMBARCADERO TERMINAL

This discussion describes the likely sequence of operations at the Embarcadero Station in so far as they effect train scheduling.

Assumptions:

Station configuration:
(approximate)



Signal lay-out: See attached drawing (next page)

Maximum speeds: See signal lay-out drawing. In summary:

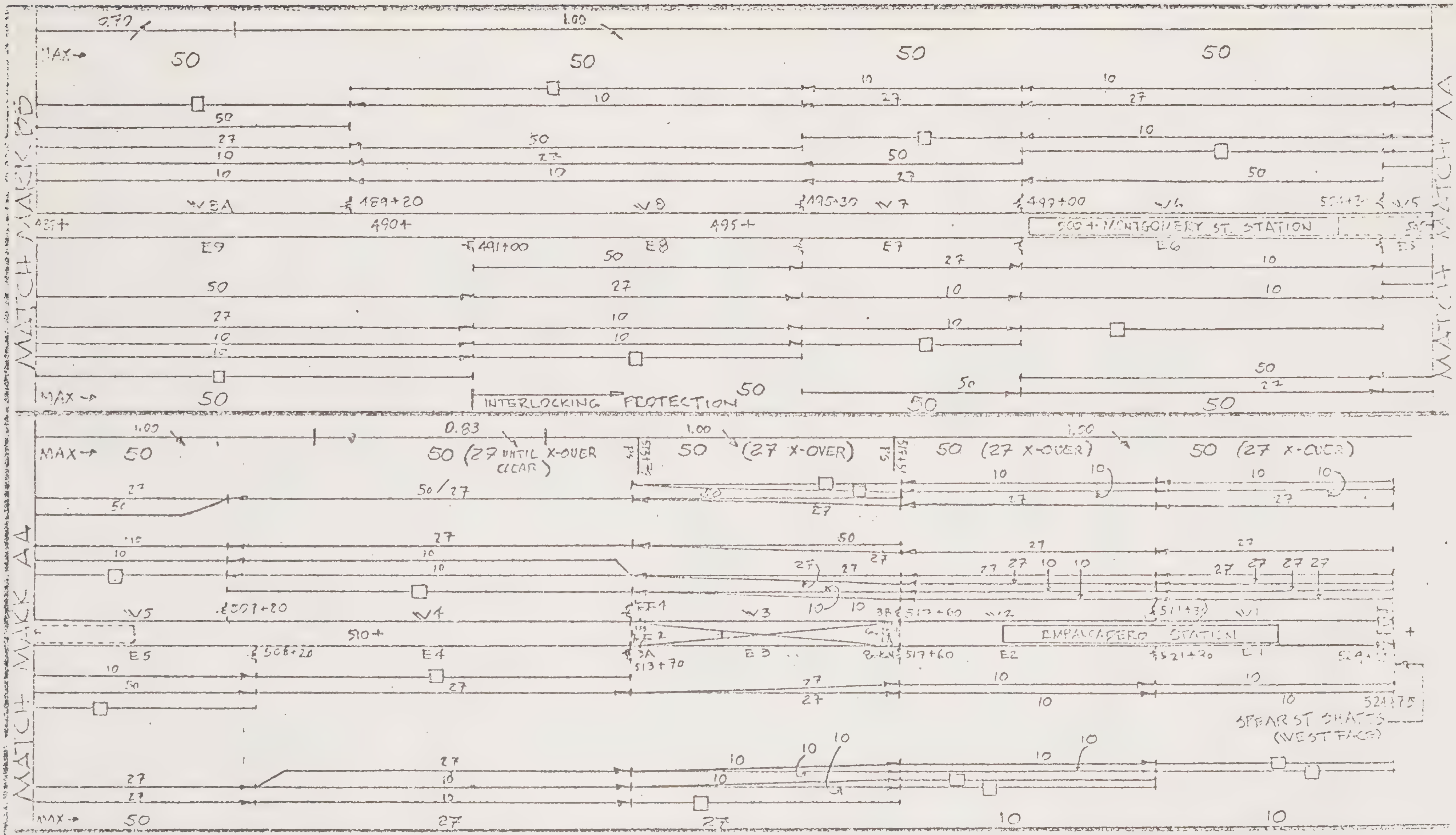
Entering station:	27 MPH	approaching cross-over to station
	10 MPH	within station
Leaving station:	50 MPH	from TL track (straight track)
	27 MPH	from TR track (cross-over move)

Train length: Three-car train, 210 feet.

Time required to clear cross-over interlocking for next train move: 10 seconds.

Distance from front of LRV to signal pickup coil--7.5 feet.

However, a figure of 10 feet was used in calculations to allow for the 1 second allowable delay in an operator's response to a restricting cab signal indication.



MUNICIPAL RAILWAY OF SAN FRANCISCO–SUBWAY SIGNAL LAYOUT

SCALE: 1" = 200'

CONTRACT Nº MR-588

DRAWING 1 OF 10

DR BY: BEM

CH. BY WCS

LOUIS T. KLAUDER AND ASSOCIATES
CONSULTING ENGINEERS – PHILA, PA.

JUNE 16, 1972

Departure time requirements:

TL track to clear cross-over: Distance = 390' + 210' + 210' = 810'

t = 22.5 seconds

Acceleration up to 50 MPH
Time = 22.5 seconds (from time-distance plot)
(Final speed only about 43 MPH)

TR track to clear cross-over: Distance = 810'

t = 26.1 seconds

Acceleration up to 27 MPH; 217.2 feet
Time = 11.1 seconds

592.8 feet at constant 27 MPH
Time = 14.97 seconds

Arrival time requirements:

From entering cross-over block to stopping at station--either TR or TL track. Times represent a minimum to maximum range:

Clear indication for cross-over interlocking--Minimum time:

t = 10.1 + 7.7 + 17.5 = 35.3 seconds

(a) Distance = 390 ' + 10' = 400'
Constant speed, 27 MPH
Time = 10.10 seconds

(b) Distance = 210' + 210' - 10' = 410'
Slow to 10 MPH, stop at station

Deceleration 27 to 10 MPH, 10 to zero:
Time = 7.7 seconds
Distance = 152.7 feet

Constant 10 MPH
Distance = 410 - 152.7 = 257.3 feet
Time = 17.54 seconds

From stop before cross-over (interlocking blocked)--Maximum time:

t = 11.1 + 9.15 + 7.7 + 17.5
= 45.5 seconds

(a) Distance = 400'

Acceleration up to 27 MPH
Time = 11.1 seconds
Distance = 37.8 feet

Constant 27 MPH
Distance = 400 - 37.8 = 362.2 feet
Time = 9.15 seconds

(b) Same as above.

Schedule:

A 2-minute headway would give the following optimal sequence of terminal movements.

Tr	Dir	Tk	Lv	Clear/Enter Crossing	Ar	Trk's Occ.	Track Boarding	Available Dwell
01	OB	TL	00:00	00:23		TR	TR	
03	IB	TR-TL		00:33	01:08/01:19	TL,TR	TR	01:20 to 04:00
02	OB	TR-TL	02:00	02:26		TL	TL	
04	IB	TR		02:36	03:11/03:22	TL,TR	TL	03:25 to 06:00
03	OB	TL	04:00	04:23		TR	TR	
05	IB	TR-TL		04:33	05:08/05:19	TL,TR	TR	05:20 to 08:00
04	OB	TR-TL	06:00	06:31		TL	TL	

The relationship between headway and available terminal dwell is:

Available dwell T = 2h-01:25 (where h = headway)

headway (minutes)	dwell (minutes)
1:30	1:35
2:00	2:35
2:30	3:35

Comments

First, it should be noted that these schedule estimates do not include any slack--and it would be unrealistic to assume these optimal times will often be achieved, considering variations in running times, passenger loads, individual vehicle and operator characteristics, etc.

It is also possible that the terminal dwell may have to allow for the following sequence of operator actions (assuming one operator on each car of a train). While this sequence is compatible with a conservative reading of the LRV specs, it would lead to some obvious operational difficulties when working with tight headways, if the LRVs as built do conform to this interpretation. Several points need to be and are being clarified with the LRV contractor.

1: Stop train, allow passengers to exit, close doors, deactivate "front" cab controls.

2: Move to other end of LRV, enter and set up cab, activate console controls.

3: (Operator on new "front" car) Check by radio with other operators and/or tower to confirm train consist, and manually enter destination identification for each car on wayside panel to set Duboce interlocking switches and Embarcadero station signs.

4: Open doors to load passengers.

5: Close doors (each car independently). Operator on lead car must depress wayside "Departure" button and can move train as soon as all doors are closed and he receives his indication.

--Peter Straus

Sep. 10, 1974 ①

To: E.M. Duarte
M. R. Cohn

From: H.D. Quimby

Subject: LRV Coupling-Uncoupling

Reference: Aug. 15, 1974 letter from R.D. Tonton, Jr. (L.T. Klauder & Assocs.) to T.A. Mullaney (LRV Program Manager-TI)

Yesterday I received & reviewed this letter with interest. Topics which probably have occurred to you & did to me on review included:

1. Passenger capacity considerations? Capacity need for coupling? Initially? Later?
2. Dirt & corrosion on coupler contact points?
3. Coupler casings to protect from 2., and effects on timing of coupling-uncoupling?
4. Time required to couple and check-out?
5. " " " uncouple " " " ?
6. Specific coupling procedure & rules?
7. Times of day of coupling?
8. Ditto: uncoupling (6.+7.)?
9. Where occur?
10. Coupling-uncoupling areas' site & layout plans?
11. Additional personnel required? Personnel arrangements? Platform? Inspec.? Other?

12. Swiveling, securing, + unsecuring couplers?

13. Additional operating costs involved?

14. More specifics on actual procedures + conditions cited in letter at: SEPTA, Toronto, Munich, etc. — as relevant to proposed Muni coupling - uncoupling?

This is just a list of thoughts you might want to compare with your own. We could discuss any of these when there is an opportunity.

Dean Quinby

C.C.: T. A. Mullaney
C. C. Bertoni (+ transp. Asst. Supts)

MEMO

San Francisco Municipal Railway

To: H.D. QUINBY

From: PETER STRAUS

Date: OCTOBER 23, 1974

Subject: EMBARCADERO TERMINAL--MINIMUM TRAIN-IN/TRAIN-OUT TIMES

Train flow through the Embarcadero appears to reach saturation at an average headway of 80 seconds between 3- and 4-car LRV trains, giving a dwell time of 85 seconds.

Assuming availability of other operators ready to board each car to take the train outbound, 1:25 (min:sec) should be sufficient for nominal terminal operations, but it provides no slack at all in train moves involving a cross-over move.

It should be remembered however that operation of such a schedule would require split-second coordination of 8 operators per 4-car train. Any such operation would probably be more readily achieved if the crew change took place at Montgomery rather than Embarcadero, which would give each operator added time to set his seat and mirrors, get his things together etc. Even so, if 85-seconds dwell represents a minimal zero-slack schedule, use of a 120 second dwell-schedule (35 seconds slack)--i.e., 105-second headways--should probably be considered a minimum achievable goal for a smooth reliable operation. (Thirty seconds slack seems a reasonable and acceptable minimum for a subway-surface operation, particularly under manual control.)

MINIMUM TIME SCHEDULE

Tr	Dir	Tk	Lv	Clear/Enter Crossing	Ar	Trk's Occ.	Track Boarding	Time at Platform
01	OB	TL	0:00	0:23		TR	TR	
03	IB	TR-TL		0:33	1:08/1:19*	TL,TR	TR	1:20 to 2:45
02	OB	TR-TL	1:20	1:46		TL	TL	
04	IB	TR		1:56	2:31/2:42	TL,TR	TL	2:45 to 4:05
03	OB	TL	2:45	3:08		TR	TR	
05	IB	TR-TL		3:18	3:53/4:04	TL,TR	TR	4:05 to 5:30
04	OB	TR-TL	4:05	4:36		TL	TL	

*Note: A following train could actually depart before a preceding arrival actually comes to a full stop. However, 10 seconds would have to be allowed for the signal to clear and switch to align. These factors would roughly cancel out.

1:20 (=:80) Headway; 1:25 Dwell (min:sec)

MEMO

San Francisco Municipal Railway

To: GEORGE DUARTE

From: PETER STRAUS

Date: DECEMBER 17, 1974

Subject: EMBARCADERO STATION ADDITIONS

A. Breaking through the BART vent shafts

Because of the cantilevered station mezzanine design and locations of adjacent property lines, I think we can agree that any extension at Embarcadero station, for a loop, a stub, or a route extension, must continue straight past the immediate present back wall of the station, through the BART vent shafts. This limited modification of the present structures may therefore be justified now, prior to full BART service, regardless of the specific alignment selected--or even if the line is extended at all at this time.

When Harry Foster was up here a few weeks ago, he described the differences between the long stub and the long loop alignments as "minor details". While for operations they are clearly not minor details, in construction they may be: in Foster's designs, the most intricate construction involves the breaking through of the vent shaft and the tunneling toward the surface which is common to both schemes. It is hard to envision any worthy alignment which does not cut straight through the BART vent shafts.

B. Alignment beyond the station

Any beyond-the-station turnback facility has the advantage of removing all passenger activity from the time-slot available to physically reverse trains. Thus, a two-track stub with crossovers beyond the station does not allow trains to be reversed appreciably quicker than the existing arrangement, excepting to the degree that passenger interference is eliminated. At a busy downtown terminal station, this interference could be appreciable and the beyond-the-station two-track stub would be advantageous. For example, it could make train reversal without a "fall-back crew" realizable.

The speed and efficiency with which a beyond-the-station stub can function is related to the number of tracks included. A two-track stub would allow a more efficient and dependable operation, but at about the same minimum headway, as the present station alignment.

A single-track stub, however, as shown on Harry Foster's drawing, would generally require more time, which translates into longer headways than the present alignment. That specific alignment should be avoided.

A fully useable three-track stub, on the other hand, does have the potential of allowing both increased efficiency and dependability, and possibly decreased minimum headways. The advantages are derived by affording each train a longer interval in which to change operating cabs and physically reverse direction.

However, any stub terminal will be limited by the conflicting movement of trains across switches--and hence to a minimum theoretical headway of perhaps 80 - 90 seconds (?).

This is the operational advantage of a loop--it does not involve switching or crew repositioning; hence, terminal headway is theoretically constrained by only the same factors as constrain line headway. Thus, a slower speed system, operating at, say, 45 second headways, could only be accommodated by a loop terminal alignment. If we are unable to couple cars into trains as planned, system redesign to this type of operation--similar to MBTA's Boston and SEPTA's Philadelphia subway-surface operations--is about the only way Muni might accommodate all five streetcar lines operating independently via the Market Street subway.

This makes a loop alignment, which is functionally simplest under any mode of operation, difficult to reject until we have at least gained some experience with the LRVs.

The second issue at stake at Embarcadero is, of course, car storage. Of the alignments described above, the three-track stub arrangement is probably best for storage; its advantage as a terminal is mirrored in its advantages for access to cars from any track, to any track. However, the additional switchwork may present problems in terms of the added stub length required to accommodate four-car trains.

Going back to zero, our best approach to storage might be to decide what our preferred, optimum storage capacity would be, and then to see how and where it might be accommodated. We are not necessarily limited to three or five or seven trains only.

Memorandum (PS)
December 17, 1974
Re: Embarcadero Station Additions

C. Cut-and-cover construction vs. tunneling

Any cut-and-cover construction on Lower Market street, no matter how limited, is likely to encounter intense opposition at this time. Any possibility of limiting construction to tunneling methods should be fully explored.

D. Timing

Although it may seem desirable to complete any construction by mid-1976, I do not feel it is absolutely necessary to do so: although it will be a tight operation with little flexibility, I feel the present system, given a two-minute headway and coupling of cars into trains, can be made to work.

Before we can commit ourselves to any of the present alternatives, several options remain to be explored--including vehicle modification either in place of or in addition to reconstruction of the Embarcadero Station.

PS

March 24, 1975

TO: C. E. Green

FROM: H. D. Quinby

SUBJECT: LRV: Tram

REFERENCES: My earlier memoranda on this subject.

1. Summary

There is no question at all that a loop at the downtown San Francisco LRV terminal is far superior, from the operating standpoint, to any kind of stub terminal there. A loop should have been demanded from the beginning and no further planning should preclude its ultimate provision wherever that terminal is located.

2. Initial Stub

Light Rail Vehicle (LRV) subway operations will have to start, however, with the present stub and near-side scissors crossover at Embarcadero Station, because no major construction changes could be completed until long after such start in 1976 or 1977. This means 2-1/2-to-2-minute minimum headways downtown, or 12-1/2-to-10-minutes per average line, without on-line coupling at West and Duboce Portals. Patrons today enjoy about 2-to-5-minute average headways per line during peaks, and about 5-to-[illegible]-minutes during the weekday base.

3. Farside Crossover

Relocation of the main Embarcadero crossover from the near (west) to the far (east) end of the station platform would only reduce the minimum headway by about 1/2-minute: to 2-to-1-1/2-minutes, or 10-to-7-1/2-minutes per average line without on-line coupling. It would not likely eliminate on-line, close-headway coupling and uncoupling.

It is very questionable whether a 1-1/2-minute minimum downtown headway could be reliably and continuously achieved in this stub configuration. The only main headway reduction gained by shifting from near-to-far-side stub crossover is the removal of one station dwell increment from the headway.

If such a major construction project were financially possible, it should include instead a single-track loop, with adjacent storage for up to about four LRV units.

4. Loop Advantages

A loop will avoid the need for a complex, continuous drop-back crew arrangement required with a stub on short headways. Repeated changing of cabs and ends will not be required. Operation is simplified and optimized at the terminal. A single-track loop with 4-car storage track would involve cost magnitudes of a range not far different from an elaborate multi-track, far-side, multi-crossover stub layout, and perhaps even lower magnitude.

A loop will enable minimum headways to be reduced to about one minute without serious compromise of overall LRV system travel time. Headways as low as 1/2-to-3/4-minute are practical for single LRV units, with reductions in line speed. A one-minute downtown headway would easily provide 9,000 passengers-per-hour-per-track capacity with single LRVs. On-line coupling would then be unnecessary.

5. Peak Patronage

Last November the streetcars totalled 5,000 passengers per hour in the peak direction at the maximum load point, with a 5,100 hourly rate in the crest-peak 15 minutes there. With nearby BART and other parallel routes, and a relatively stable San Francisco population trend, it is unlikely that patronage will exceed 9,000 hourly, if it even approaches that level.

6. Major Questions

Major unresolved questions in this context now include:

1. What will crest-peak patronage actually be?

2. Will on-line close-headway coupling and uncoupling work reliably, day-in and day-out?

3. Can the already-planned signal hardware in the West Portal-Embarcadero trunk section be practically adjusted to make best use of the much lower headways and much better operations possible with a downtown loop?

Question 1. is discussed in Section 5. above.

7. As to Question 2:

(A) Continuously reliable operation with on-line, close-headway (2-1/2-to-1-1/2-minutes in the trunk section) coupling and uncoupling has not yet been effectively demonstrated for Muni conditions.

(B) Boeing's Preliminary LRV Operator Training Manual raises significant questions about such operation (especially Manual Sections 4-10-3 and 4-10-4).

(C) The whole coupling hardware system remains yet to be rigorously demonstrated to Muni in this kind of operation.

(D) Surface traffic congestion will delay LRVs, yet they need to couple with very close time-precision to make such an operation work well.

(E) It will require expensive extra manpower to supervise continuously at coupling and uncoupling points.

(F) Additional expensive control and display hardware, cabinetry, and geometric provisions are necessary at both West and Duboce Portals with this coupling-uncoupling operation.

(G) Such an operation does not appear ever to have been successfully accomplished, under conditions similar to those at West and Duboce Portals, anywhere in the world. Repeated attempts by others to demonstrate to the contrary have been shown to be inapplicable in every case put forward.

(H) For basic reasons set forth in this memorandum, no, or virtually no, similar operation and physical tram layout in the world terminates with multiple routes in a downtown stub. Philadelphia, Boston, Shaker Heights, and developing tram-subway systems in Europe all have loops, not stubs, at their major terminals and, usually, at outer terminals too.

8. As to Question 3:

It does not appear that this signalling question has yet been definitively investigated and answered. It should be. Optimum LRV speed and travel-time capabilities, with a variety of minimum headways well below 1-1/2-minutes, should be obtainable, so as to make the needed downtown loop work as effectively as possible. The present design assumes the very cumbersome present stub terminal at Embarcadero and has only three basic speed steps: 50 mph (line running), 27 mph (through crossovers), and 10 mph (closing-in at stations).

9. Initial Coupling

Given the present inadequate Embarcadero Terminal configuration, expected patronage volumes, and needs for reasonable headways on each of the five LRV routes, it appears inescapable that, for several years at least, LRVs will have to be coupled and uncoupled on-line at West and Duboce Portals, at least during broad peak periods, unless the operationally better two-car-

train alternative cited below can be implemented. If base period headways beginning to approach those already provided will be demanded, then coupling-uncoupling will have to occur off-peak too. However, even for the initial LRV operations period, there is potentially a more attractive operational alternative, provided three questions can be satisfactorily answered. See Section 10 below.

10. Two-Car Trains Throughout

If (i) passengers would tolerate the somewhat longer headways on each route (see Section 2. above), if (ii) the surface-lines' stops can be built for two-car LRV trains, and if (iii) PM peak-downtown platform congestion from waiting passengers can be resolved, then operation of two-car trains throughout most or all LRV routes would be a much more practical alternative than on-line coupling-uncoupling. In this alternative, coupling-uncoupling would occur only a few times a day when consist-changes are needed, and then only at terminals and other appropriate spots. This attractive alternative should be further investigated, particularly if on-line close-headway coupling-uncoupling, on rigorous test, turns out to be less reliable than Muni service needs require.

11. Conclusion

For the longer run, the best, and probably only practical, operating solution is to build a loop as soon as possible at the downtown LRV terminal.

H. D. Quinby

H. D. Quinby

cc: G. M. Duarte
Rino Bei
J. J. Finn
C. C. Barton
M. F. Ittig
F. J. Scheifler
T. A. Mullaney
P. S. Straus

August 26, 1976

MEMORANDUM

To: C. E. Green

From: H. D. Quinby

Subject: LRV Coupling - Uncoupling

Reference: My March 24, 1975 & other memoranda on this subject.

From the evolving site, vehicle, operating, and related characteristics, it is continuing to become increasingly apparent that on-line, close-headway LRV coupling-uncoupling at West and Duboce Portals is not the most practical, or even a practical, solution to the problem presented principally by the lack of a loop at or near the Embarcadero terminal station.

Instead, as proposed in Section 10 of my March 24, 1975 memorandum, operation of two-car LRV trains throughout most or all LRV routes when needed increasingly appears as a much more practical alternative. In this alternative, coupling-uncoupling of a train would occur only a few times a day when and as consist-changes are needed, and then only at terminals or other functionally appropriate locations. As noted in the abovementioned memorandum, this alternative will require somewhat longer headways on each route, arranging surface stops to accommodate two-car trains, and (if actual LRV patronage were high enough) resolving potential PM peak downtown station platform congestion conditions if any such conditions in fact occur. The most recent streetcar counts at the Van Ness Avenue maximum load point indicate maximum hourly volumes of about 4,600 - 4,800 total passengers on all five lines in the peak direction.

The physical characteristics particularly at the Duboce Portal area, the time increments likely to be involved in coupling-uncoupling, safety aspects and potential damages and claims, the added supervision and other costs, crew-handling and assignment aspects, the uncertainties and unevenness of inbound LRV arrivals at West and Duboce Portals, and uncertainties of continuously reliable operation of the coupling elements involved, all militate against regular on-line, close-headway coupling-uncoupling of trains at West & Duboce Portals. These and other related points are discussed in detail in my March 24, 1975 LRV memorandum.

Accordingly, it is recommended that major future LRV implementation planning address the more practical alternative recited in the second paragraph of this memorandum. It is also recommended again that design and construction of a proper operating loop at the downtown San Francisco LRV terminal be undertaken at the earliest possible time.

H.D. Quinby

Henry D. Quinby

cc: G. M. Duarte
R. Bei
T. A. Mullaney
M. R. Cohn
M. F. Ittig
J. L. Beckham
P. S. Straus
C. C. Barton
R. J. Jordan

Appendix C:

Raptran Sumulation Program - Sample Output

BLOCK I.D.	E11-POW	E10	E9	E8	E7	E6-MON	E5	E4	E3	E2-EMB
BLOCK LENGTH (FEET)	505.00	382.00	655.00	429.00	377.00	505.00	411.00	548.00	391.00	467.00
BLOCK MAX SPEED (MPH)	0.00	50.00	50.00	50.00	49.00	0.00	50.00	27.00	27.00	0.00
BLOCKS TO CLEAR	4	4	4	4	4	4	5	3	3	1
MAX SPEED--BLOCK OCCUPIED	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
MAX SPEED--1 BLOCK CLEAR	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	***.00
MAX SPEED--2 BLOCKS CLEAR	10.00	27.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	***.00
MAX SPEED--3 BLOCKS CLEAR	27.00	27.00	27.00	27.00	27.00	27.00	27.00	10.00	10.00	***.00
MAX SPEED--4 BLOCKS CLEAR	***.00	***.00	***.00	***.00	***.00	***.00	27.00	***.00	***.00	***.00

VEHICLE PERFORMANCE SUMMARY:

NOMINAL ACCELERATION RATE	2.00 MPHPS
NOMINAL SERVICE BRAKING RATE	3.50 MPHPS
NOMINAL EMERGENCY BRAKING RATE	6.00 MPHPS

SCHEDULE SUMMARY:

DEP TIME	TRAIN	TRACK	FROM	TO
759.75	1	1	E11-POW	E2-EMB
800.25	2	2	E11-POW	E2-EMB
800.75	3	3	E11-POW	E2-EMB
801.00	4	1	E11-POW	E2-EMB
801.25	5	2	E11-POW	E2-EMB
801.74	6	3	E11-POW	E2-EMB
802.25	7	1	E11-POW	E2-EMB
802.26	8	2	E11-POW	E2-EMB
802.95	9	3	E11-POW	E2-EMB
803.26	10	2	E11-POW	E2-EMB
803.50	11	1	E11-POW	E2-EMB
804.09	12	3	E11-POW	E2-EMB
804.26	13	2	E11-POW	E2-EMB
804.75	14	1	E11-POW	E2-EMB
805.07	15	3	E11-POW	E2-EMB
805.27	16	2	E11-POW	E2-EMB
806.00	17	1	E11-POW	E2-EMB
806.06	18	3	E11-POW	E2-EMB
806.27	19	2	E11-POW	E2-EMB
807.51	20	3	E11-POW	E2-EMB

	0.										
	0.0										
TIME = 801.29	0.0	0.0									
DELTA = 0.0874	0.0	0.0	0..								

	0.0	0.0	801.44	0.0					
	0.0	0.0	50.00	0.0	0.0				
TIME = 801.36	0.0	801.52	0.0	0.0	0.0	0..			
DELTA = 0.2790	0.0	32.28	0.0	0.0	0.0	0.0	[illegible]		
	0.0	0.0	0.0	0.0	[illegible]	0.0	0.0		
	0.0	0.0	0.0	0.0	[illegible]	0.0	0.0	0.0	

TIME = 801.37	0.0	0.0	801.44	0.0	0.0	0.0	0.0	0.0	801.53	0..	
DELTA = 0.1546	0.0	0.0	50.00	0.0	0.0	0.0	0.0	0.0	27.00	0.0	In
	0.0	801.52	0.0	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	801.38	0.0	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	49.00	0.0	0.0	0.0	0.0	0.0	

TRAIN 3 15-SECOND STATION STOP AT "E6-MON " AT 801.61
TIME FROM "E11-POW" (800.75 DEP) TO "E6-MON " STA (801.86 DEP) IS 1.11 MIN; 0.0 MIN DELAY

	0.0	0.0	801.44	0.0	0.0	0.0	0.0	0.0	801.53	0.0	
	0.0	0.0	50.00	0.0	0.0	0.0	0.0	0.0	27.00	0.0	
	0.0	801.52	0.0	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
TIME = 801.38	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	STATION STOP
DELTA = 0.4834	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TR 3 AT BLOCK E6-MON

TIME = 801.44	0.0	0.0	0.0	801.54	0.0	0.0	0.0	0.0	801.53	0.0	
DELTA = 0.0975	0.0	0.0	0.0	50.00	0.0	0.0	0.0	0.0	27.00	0.0	TR 4 AT BLOCK E8
	0.0	801.52	0.0	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

BLOCK I.D.	E11-POW	E10	E9	E8	E7	E6-MON	E5	E4	E3	E2-EMB	
BLOCK LENGTH (FEET)	505.00	382.00	655.00	429.00	377.00	505.00	411.00	548.00	391.00	467.00	
BLOCK MAX SPEED (MPH)	0.00	50.00	50.00	50.00	49.00	0.00	50.00	27.00	27.00	0.00	
	0.0	0.0	0.0	801.54	0.0	0.0	0.0	0.0	801.53	0.0	
	0.0	0.0	0.0	50.00	0.0	0.0	0.0	0.0	27.00	0.0	
TIME = 801.52	0.0	0.0	801.69	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
DELTA = 0.1750	0.0	0.0	50.00	0.0	0.0	0.0	33.48	0.0	0.0	0.0	TR 5 AT BLOCK E9
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

TRAIN 1 15-SECOND STATION STOP AT "E2-EMB " AT 801.79
TIME FROM "E11-POW" (799.75 DEP) TO "E2-EMB " STA (802.04 DEP) IS 2.29 MIN; 0.0 MIN DELAY

TIME = 801.53	0.0	0.0	0.0	801.54	0.0	0.0	0.0	0.0	0.0	802.04	STATION STOP
DELTA = 0.5105	0.0	0.0	0.0	50.00	0.0	0.0	0.0	0.0	0.0	0.0	TR 1 AT BLOCK E2-EMB
	0.0	0.0	801.69	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	0.0	50.00	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

TIME = 801.54	0.0	0.0	0.0	0.0	801.63	0.0	0.0	0.0	0.0	802.04	
DELTA = 0.0374	0.0	0.0	0.0	0.0	49.00	0.0	0.0	0.0	0.0	0.0	TR 4 AT BLOCK E7
	0.0	0.0	801.69	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	0.0	50.00	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

TRAIN 4 15-SECOND STATION STOP AT "E6-MON " AT 801.86
TIME FROM "E11-POW" (801.00 DEP) TO "E6-MON " STA (802.11 DEP) IS 1.11 MIN; 0.0 MIN DELAY

TIME = 801.63	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	STATION STOP
DELTA = 0.4834	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TR 4 AT BLOCK E6-MON
	0.0	0.0	801.69	0.0	0.0	0.0	801.64	0.0	0.0	0.0	
	0.0	0.0	50.00	0.0	0.0	0.0	33.48	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TIME = 801.64	0.0	0.0	801.69	0.0	0.0	0.0	0.0	801.87	0.0	0.0	
DELTA = 0.2269	0.0	0.0	50.00	0.0	0.0	0.0	0.0	27.00	0.0	0.0	TR 2 AT BLOCK E4
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TIME = 801.69	0.0	0.0	0.0	801.79	0.0	0.0	0.0	801.87	0.0	0.0	
DELTA = 0.0975	0.0	0.0	0.0	50.00	0.0	0.0	0.0	27.00	0.0	0.0	TR 5 AT BLOCK E8
	0.0	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	801.79	0.0	0.0	0.0	801.87	0.0	0.0	
TIME = 801.74	0.0	0.0	0.0	50.00	0.0	0.0	0.0	27.00	0.0	0.0	
DELTA = 0.0	801.74	0.0	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	DEPARTURE
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TR 6 AT BLOCK E11-POW

BLOCK I.D.	E11-POW	E10	E9	E8	E7	E6-MON	E5	E4	E3	E2-EMB	
BLOCK LENGTH (FEET)	505.00	382.00	655.00	429.00	377.00	505.00	411.00	548.00	391.00	467.00	
BLOCK MAX SPEED (MPH)	0.00	50.00	50.00	50.00	49.00	0.00	50.00	27.00	27.00	0.00	
	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	801.79	0.0	0.0	0.0	801.87	0.0	0.0	
	0.0	0.0	0.0	50.00	0.0	0.0	0.0	27.00	0.0	0.0	
TIME = 801.74	0.0	802.01	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
DELTA = 0.2690	0.0	32.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	TR 6 AT BLOCK E10

TRAIN 5 RESTRICTED SPEED IN BLOCK "E7 " FROM 801.79 TO 801.87 BEHIND TRAIN 2
SPEED OF 34.00 MPH REACHED BEFORE BLOCK "E4 " CLEARED.

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TIME = 801.79	0.0	0.0	0.0	0.0	801.90	0.0	0.0	801.87	0.0	0.0	RESTRICTED SPEED
DELTA = 0.1064	0.0	0.0	0.0	0.0	37.64	0.0	0.0	27.00	0.0	0.0	TR 5 AT BLOCK E7
	0.0	802.01	0.0	0.0	0.0	801.86	0.0	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	801.90	0.0	0.0	801.87	0.0	0.0	
	0.0	0.0	0.0	0.0	37.64	0.0	0.0	27.00	0.0	0.0	
TIME = 801.86	0.0	802.01	0.0	0.0	0.0	0.0	802.14	0.0	0.0	0.0	
DELTA = 0.2790	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	TR 3 AT BLOCK E5

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TIME = 801.87	0.0	0.0	0.0	0.0	801.90	0.0	0.0	0.0	802.03	0.0	
DELTA = 0.1645	0.0	0.0	0.0	0.0	37.64	0.0	0.0	0.0	27.00	0.0	TR 2 AT BLOCK E3
	0.0	802.01	0.0	0.0	0.0	0.0	802.14	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	

TRAIN 5 15-SECOND STATION STOP AT "E6-MON " AT 802.14
TIME FROM "E11-POW" (801.25 DEP) TO "E6-MON " STA (802.39 DEP) IS 1.14 MIN; 0.0 MIN DELAY

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TIME = 801.90	0.0	0.0	0.0	0.0	0.0	802.39	0.0	0.0	802.03	0.0	STATION STOP
DELTA = 0.4919	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.00	0.0	TR 5 AT BLOCK E6-MON
	0.0	802.01	0.0	0.0	0.0	0.0	802.14	0.0	0.0	0.0	
	0.0	32.28	0.0	0.0	0.0	0.0	33.48	0.0	0.0	0.0	

	0.0	0.0	0.0	0.0	0.0	802.11	0.0	0.0	0.0	802.04	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	0.0	0.0	0.0	0.0	0.0	802.39	0.0	0.0	802.03	0.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.00	0.0	
TIME = 802.01	0.0	0.0	802.18	0.0	0.0	0.0	802.14	0.0	0.0	0.0	
DELTA = 0.1759	0.0	0.0	50.00	0.0	0.0	0.0	33.48	0.0	0.0	0.0	TR 6 AT BLOCK E9

TRAIN 2 15-SECOND STATION STOP AT "E2-EMB " AT 802.29
TIME FROM "E11-POW" (800.25 DEP) TO "E2-EMB " STA (802.54 DEP) IS 2.29 MIN; 0.0 MIN DELAY